MATERIALS BUREAU

TECHNICAL REPORT 91-4

EVALUATION OF A HIGHWAY TRAFFIC NOISE SCREEN FEATURING FANWALL MODULAR CONCRETE PANELS

AUGUST, 1991

MAP CODE 7.42-6-91-4

NEW YORK STATE DEPARTMENT OF TRANSPORTATION

MARIO M. CUOMO, Governor

FRANKLIN E. WHITE, Commissioner

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EVALUATION OF A HIGHWAY TRAFFIC NOISE SCREEN FEATURING FANWALL MODULAR CONCRETE PANELS

Final Report On Experimental Feature Project 76-07
Conducted In Conjunction With
The U.S. Department of Transportation
Federal Highway Administration

Prepared by

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August 15, 1991

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M.A.P. CODE 7.42-6-91-4

PREFACE

FANWALL precast modular concrete noise walls were constructed on compacted earth berms in three locations along New York State's Genesee Expressway, I-390. Designers used a computerized noise level prediction program to determine the optimum height and location of the noise wall installations. During the initial phases of construction, two of the concrete noise walls showed signs of foundation failure. To remedy the problem, reinforced concrete footings were installed at the ends of the walls and under the taller modular panels. The effectiveness of the barrier/berm installations was determined using barrier insertion loss. Calculations showed a reduction in measured noise levels of between 13 and 16 dBA. In each case, the noise level at the sensitive receptor was reduced to a value below the desired target. The accuracy of the computerized noise level prediction model is examined.

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TABLES

ILLUSTRATIONS

I. INTRODUCTION

A. Background

In recent years the public has been exposed to increasing highway noise levels resulting from growing traffic volumes and larger percentages of truck traffic. To reduce the impact of rising noise levels, highway designers and planners have used noise screens or noise barriers along sensitive land use areas. These noise barriers usually consist of a wall, an earth berm or a combination of both.

B. Purpose

The purpose of this study is to evaluate the effectiveness of three highway noise barrier installations featuring FANWALL modular precast concrete panels installed on earth berms.

This document combines into one final report, construction information and costs, performance inspections, evaluations, conclusions and recommendations regarding the FANWALL installations constructed under Experimental Feature Project 76-07.

II. CONSTRUCTION

A. Test Sites

FANWALL modular precast concrete noise barrier was installed on earth berms at three locations along New York State's Genesee Expressway, I-390 in NYSDOT Region 4, Monroe County. (See Figure 1.) These locations are as follows:

1. Site 1 is on the southbound side of I-390, bordering the Clayton Arms Apartment Complex in the Town of Henrietta. It was constructed on Section 13 of the Genesee Expressway under contract D95646 at stations SB 290+00 through SB 312+00. The total area of precast panels installed was 24,420 sq ft. The total length of the installation was 2,200 ft.

2. Site 2 is on the northbound side of I-390, bordering the Wedgewood Park Subdivision in the Town of Henrietta. It was constructed on Section 13 of the Genesee Expressway under contract D95646 at stations NB 305+00 through NB 323+50. The total area of precast panels installed was 17,826 sq ft. The total length of the installation was 1,850 ft.

3. Site 3 is on the southbound side of I-390, bordering the Community Manor Apartment Complex in the Town of Henrietta. It was constructed on Section 14 of the Genesee Expressway under contract D95590 at stations SB 224+45 through SB 232+15. The total area of precast panels installed was 7,296 sq ft. The total length of the installation was 770 ft.

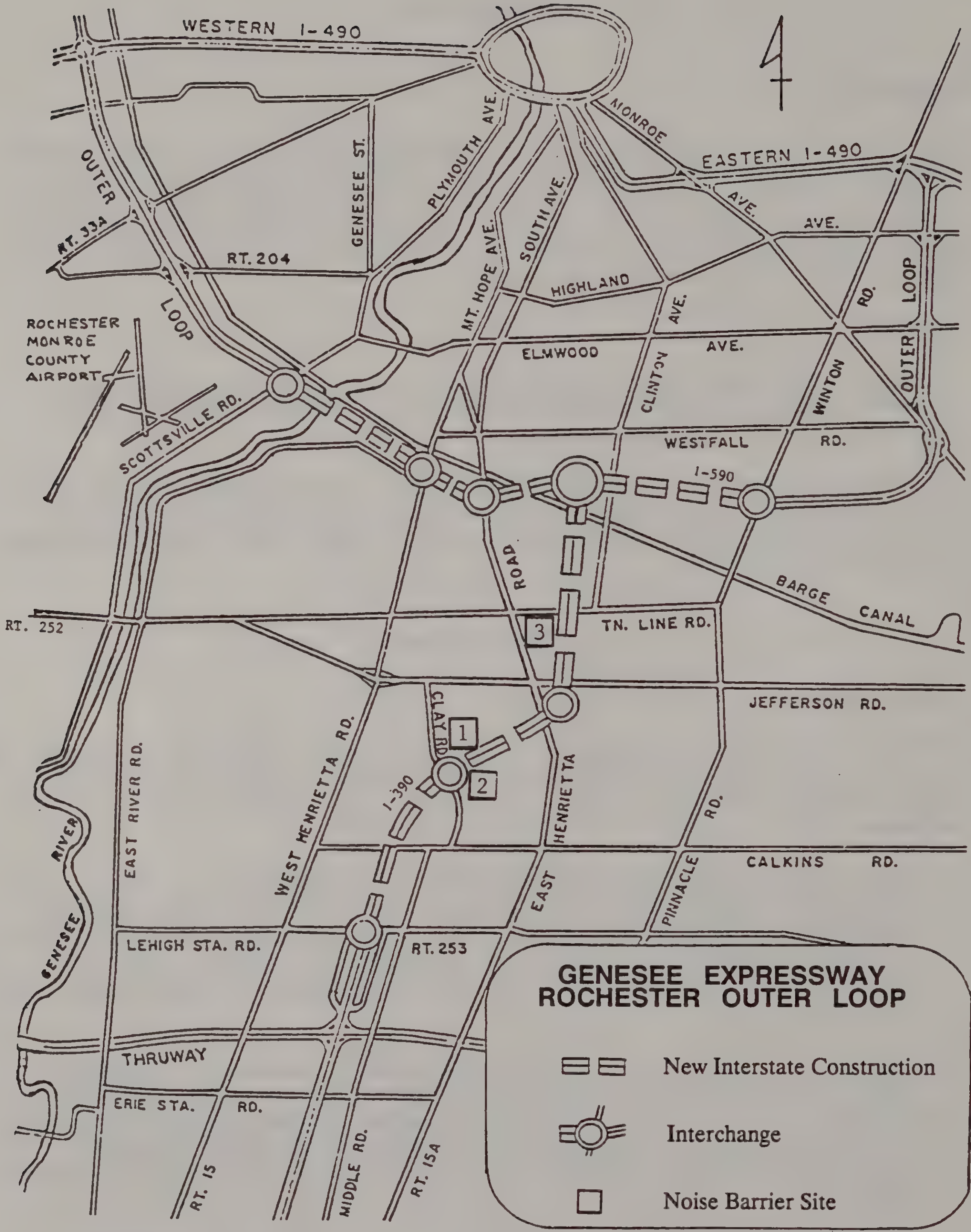


Figure 1. FANWALL NOISE BARRIER LOCATIONS

B. Barrier Design

The need for noise barriers was determined in the final Environmental Impact Statement (EIS) which studied the noise levels resulting from the construction (i.e. effects of construction) of the Genesee Expressway (I-390) from the New York State Thruway (I-90), north to the Rochester Outer Loop (I-590) (1). The noise barrier design called for modular concrete panels to be erected on compacted earth berms. The total height of barrier selected for each site was determined by the New York State Department of Transportation's computerized, highway-traffic noise-level-prediction program entitled HUSH. This program was developed by the Environmental Analysis Section, based on the acoustic propagation theory found in the National Cooperative Highway Research Program (NCHRP) Publication 117 (2). It also incorporates the barrier attenuation model found in NCHRP Publication 144 (3), with a finite barrier correction based on the Federal Highway Administration (FHWA) Report HHI-HEV-73-7976-1 (4).

The berms were constructed of a plastic till material, compacted to support the 6-inch-wide, precast concrete panels and to sustain a reversible lateral wind loading of 20 psf (80 mph). No additional foundation preparation or footings were required in the contract documents to support the vertical concrete panels. After placement of the panels, an additional one-foot of compacted fill material was to be placed on the berm above the base of the panels for wall support. The total combined heights of the panel/berm systems were 16 ft, 12 ft and 16 ft at Sites 1, 2 and 3, respectively. The combined panel/berm profiles for the three Sites are shown in Appendix A.

The barrier design called for the precast concrete wall to be connected in a free-standing trapezoidal configuration with a 45° intersecting angle between panels. The tops of the panels were placed parallel to the roadway grade to give a smooth appearance. Individual concrete panels were rectangular in shape with a concave projection on one vertical edge and a convex formation on the other vertical edge. The concave and convex edges of two adjacent panels, when mated together, formed a nested, rotable joint during installation. This rotable joint feature allows the barrier panels to be connected in a variety of configurations, including a T-joint. (See Appendix B). Optional gaskets were not used in the joints on the installations studied.

Each concrete panel was 6 ft wide and 6 inches thick, with a height of from 8 to 13 ft. They were precast using a New York State Class A concrete mix (i.e. 606 lb cement per cy, 0.46 w/c, 7.0% air, 3 ±1/2 inch slump, type CA2 aggregate gradation). Wire reinforcing fabric conformed to ASTM A82 and ASTM A185. (See Appendix C). Fabrication of the individual panels was carried out according to the production guidelines listed in Appendix D. A typical panel 6 ft by 8 ft by 6 inches weighed approximately 3,600 lbs. Fasteners used to join adjacent panels were 5/16" diameter, stainless steel 7 X 19 strand aircraft cable and tensioning clamps. The minimum rated tensile strength of the aircraft cable was 9,000 lbs. The rated strength of the tensioning clamps was to meet or exceed the cable strength.

Modular concrete panels and fasteners were specified to conform to U.S. Patent Number 3732653, as assigned to FANWALL INC., P.O. Box 868, Framingham, Massachusetts 07101. The precast concrete panels were produced by SPANCRETE NORTHEAST, INC., 8 Cairn Street, Rochester, New York 14611.

C. Installation

Placement of the first FANWALL precast concrete panels began at Site 3 on Contract D95590 in October, 1978. After preparation of the berm as described in the previous section, panels 8 ft in height were erected from Station SB 225+03 to Station SB 230+90 (i.e. approximately 587 of the total 770 linear feet of wall called for at Site 3.) The contractor on this section decided not to complete the ends of the barrier wall, each of which would terminate at a bridge abutment, until Spring, 1979.

This installation took 4 days, using a 5-man crew, a pickup truck and a tractor/trailer with boom-crane. The operation included setting and leveling panel sections, and fastening panel joints; but, did not include placement and compaction of the final 1 ft of berm material around the panels. In the trapezoidal configuration, using 6 ft wide panels, one linear foot of barrier corresponds to about 1.172 ft of installed panel width; therefore, the installation rate of 147 linear feet of barrier per day translates into approximately 29 panels per day.

In November, 1978, FANWALL precast concrete panel installation was begun on Section 13 of the I-390 construction contract D95646 at Site 1. The contractor erected 46 panels 13 ft in height at Stations SB 290+00 to SB 292+34. The panels were leveled and the rotable joints secured with cable fasteners; however, the final 1 ft of backfill material was not placed. No panels were installed at Site 2 (also contract D95646), nor were any additional panels installed at any of the three sites during the 1978-79 winter months.

In late March, 1979 the 13 ft panels at Site 1 were observed to be tilted as much as 15° from vertical. The problem was most severe at the ends of the installed panels and was apparently the result of inadequate soil support and/or differential soil support. The wet/dry cycles and freeze/thaw cycles of the preceding winter months had most likely accentuated the failure. An examination of the 8 ft panels installed at Site 3 showed minor tilting (i.e. less than 4°) on several panels at the south end of the installation and no tilting at the north end of the installation.

After an examination of field conditions and consultation with the various parties involved in the design and construction of the noise wall installations, Department of Transportation personnel decided to add a footing at the ends of each barrier installation and under the panels which were greater than 8 ft in height. (The footing consisted of a 4" thick, steel-mesh reinforced concrete slab supported on a 1 ft thick bed of compacted, graded crushed stone.) Some previously installed panels had to be removed at Sites 1 and 3 to accomplish this. Also, it was decided that the short run of 12 ft panels to be placed at Site 2 would not require a concrete footing because they were to be flanked by long stretches of 8 ft panel sections.

After the additional foundation preparations described above were finished, the panel installations at Sites 1, 2 and 3 were completed without incident. Construction of the noise barriers at Sites 1 and 2 on Section 13 were completed in September, 1979. The installation at Site 3 on Section 14 was completed in June, 1980.

The installation rate of panels at Sites 1 and 2 (not including the additional footing work, or backfilling and compaction of the final 1 ft of berm material) averaged 170 linear ft per day or about 33 panels per day.

D. Costs

The final costs of the FANWALL modular concrete noise barrier/berm installations are listed in Table 1, Table 2 and Table 3.

The area of concrete barrier placed at Site 1 was 24,420 sq ft. At the bid unit price of $6.50 per sq ft, this totalled $158,730. The additional cost of supplying a foundation at Site 1 was $99,291, which brought the unit cost of the barrier to $10.57 per sq ft. In the trapezoidal configuration, using panels from 8 to 13 ft in height, with an average panel height of 9.42 ft, the cost per linear ft was $117.28.

At Site 2, 17,826 sq ft of concrete barrier were placed. The unit price bid was $6.50 per sq ft, yielding a total original cost of $115,869. The additional foundation costs totalled $17,056, which brought the unit cost of the barrier to $7.46 per sq ft. In the trapezoidal configuration, using panels predominately 8 ft in height, the cost per linear ft was $71.85.

At Site 3, 7,296 sq ft of concrete barrier were installed. The unit price bid on this contract was $6.75 per sq ft, yielding a total original cost of $49,248. The additional foundation costs were $10,747, which yielded a unit cost of $8.22 per sq ft. In the trapezoidal configuration, using 8 ft high panels, the cost per linear ft was $77.92.

Table 1. SITE 1 NOISE BARRIER/BERM CONSTRUCTION COSTS

Description	Unit	Quantity	Unit Cost ($)	Subtotal ($)
Precast Modular Panels/Earth Berm--2200 LF	SF	24,420	6.50	158,730
Additional Foundation Costs--2200 LF				
Embankment in Place	CY	687	0.30	206
Compacted Granular Fill	CY	1,175	10.00	11,750
Concrete Footing in Place	CY	209	340.80	71,227
Remove and Reset 46 Modular Panels	LS	EA	14,206.00	14,206
Unclassified Excavation & Disposal	CY	1,409	1.35	1,902
TOTAL				$258,021

Table 2. SITE 2 NOISE BARRIER/BERM CONSTRUCTION COSTS

Description	Unit	Quantity	Unit Cost ($)	Subtotal ($)
Precast Modular Panels/Earth Berm--1850 LF	SF	17,826	6.50	115,869
Additional Foundation Costs--443 LF				
Compacted Granular Fill	CY	236	10.00	2,360
Concrete Footing in Place	CY	42	340.80	14,314
Unclassified Excavation & Disposal	CY	283	1.35	382
TOTAL				$132,925

Table 3. SITE 3 NOISE BARRIER/BERM CONSTRUCTION COSTS

Description	Unit	Quantity	Unit Cost ($)	Subtotal ($)
Precast Modular Panels/Earth Berm--770 LF	SF	7,296	6.75	49,248
Additional Foundation Costs--280 LF				
Compacted Granular Fill	CY	125	12.00	1,500
Concrete Footing in Place	CY	25	185.00	4,625
Remove and Reset 20 Modular Panels	LS	EA	4,622.00	4,622
TOTAL				$59,995

III. PERFORMANCE

A. Maintenance

To date, after 12 years, there has been no maintenance required on the three FANWALL installations. All field observations indicate that the precast panels are virtually maintenance free.

B. Aesthetics

One inspector's report described the FANWALL panels as "stark" when first erected. However, now that the earth berms have been seeded and planted with trees and shrubs, and vines are growing on some of the concrete panels, the panels blend rather well with the surrounding landscape.

C. Effectiveness

The effectiveness of each noise barrier installation in reducing traffic noise levels was determined by measurement of the barrier insertion loss. The insertion loss is defined as the difference in the noise level measured at a sensitive receptor location before and after the construction of a noise barrier. Insertion loss is a function of sound transmission through the barrier, sound diffraction over the barrier, and the effects of reflection, shielding and ground cover.

Since in this case the highway and barriers were constructed simultaneously, the insertion loss had to be determined by comparing the sound level measured at a sensitive receptor shielded by a barrier, with the sound level measured at a site nearby with no barrier shielding. Unshielded measurement sites were chosen to be as similar as possible in character and geometry to their shielded counterparts. All measurements were taken after I-390 had been opened to traffic several years and traffic patterns were well established.

The noise measurement descriptor utilized in the EIS and the noise measurement descriptor determined via field measurements was L_{10} measured in dBA. This descriptor represents the ambient sound level exceeded 10% of the time. Actual field noise levels were determined in accordance with measurement and analysis procedures found in the New York State Department of Transportation's noise measurement manual (5) and noise measurement systems operating instructions (6). Persons taking the noise measurements had been certified by the New York State Department of Transportation's Noise Measurement Unit as qualified Noise Measurement Technicians. All measurements were taken approximately 5 ft above ground level at the various measurement locations.

After completion of the noise measurements, the barrier insertion loss was calculated for each of the installations. In addition, comparisons were made between the predicted noise levels found in the EIS and the actual noise levels measured in the field. Table 4 numerically summarizes the noise study findings. Figure 2 depicts the actual versus predicted L_{10} noise levels at Site 1 and Site 2. Figure 3 depicts these parameters at Site 3.

Table 4. PREDICTED VS. MEASURED L_{10} NOISE LEVELS (dBA)

Description	Site 1		Site 2		Site 3	
	Predicted	Measured	Predicted	Measured	Predicted	Measured
Edge of Highway	76	78	75	77	75	80
Sensitive Receptor - No Barrier	76	78*	70	76*	70	75*
Sensitive Receptor - With Barrier	66	63	65	63	65	59
Barrier Insertion Loss	10	15	05	13	05	16

*Estimated, based on measurements adjacent to site in an area with no barrier.

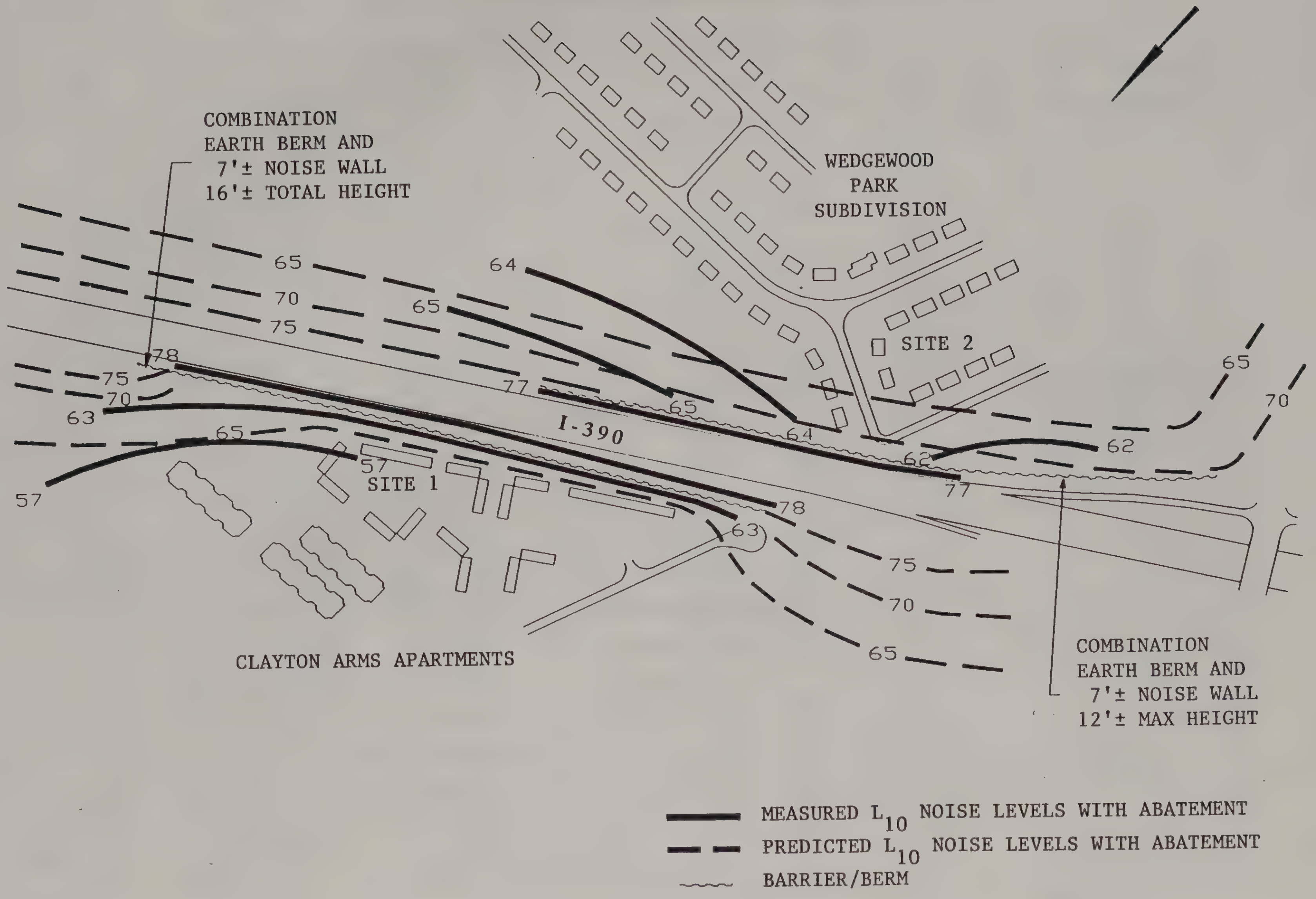


Figure 2. PREDICTED VS. MEASURED NOISE LEVELS AT SITES 1 AND 2

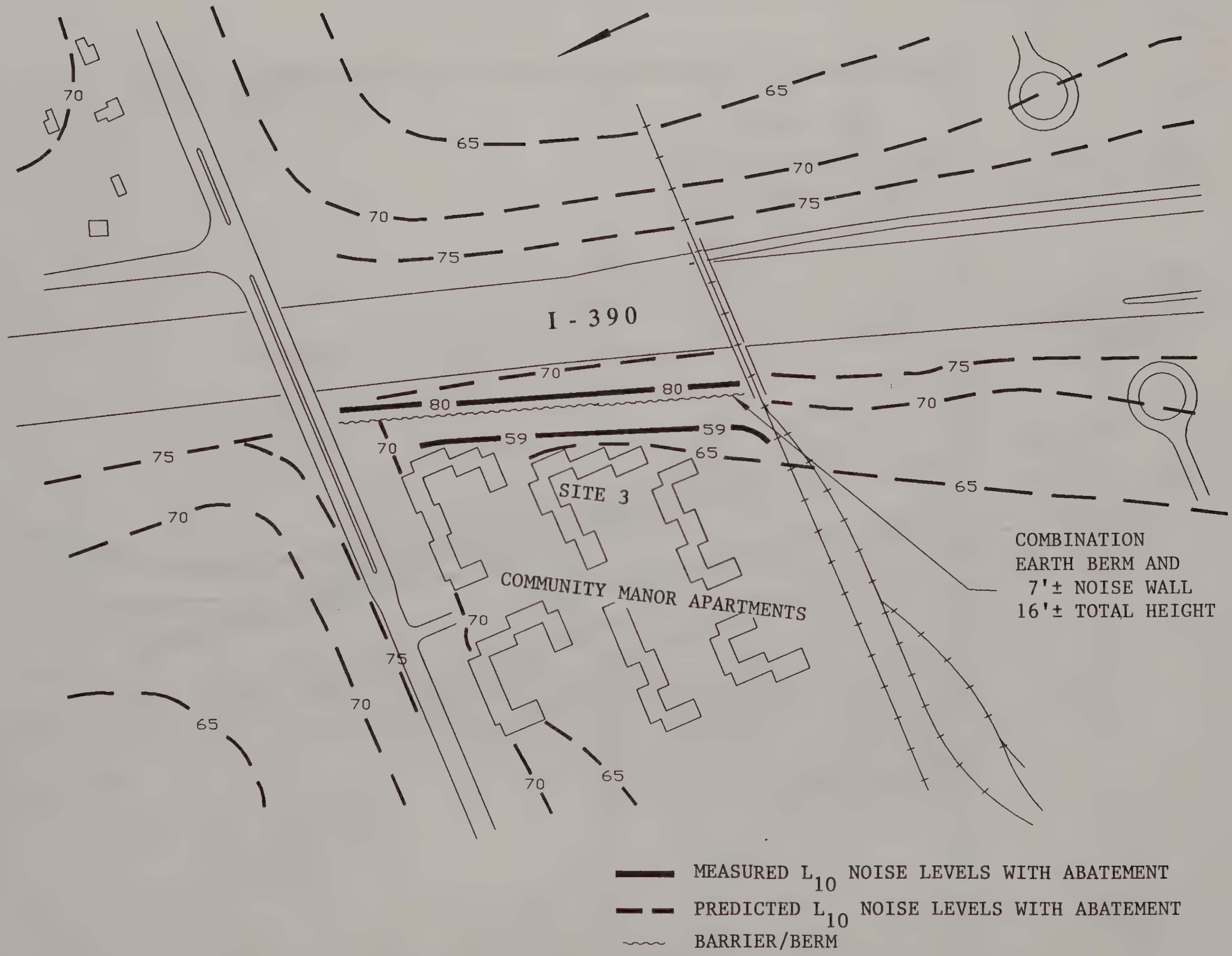


Figure 3. PREDICTED VS. MEASURED NOISE LEVELS AT SITE 3

It can be seen from the data in Table 4 that the HUSH program underpredicted the noise generated at the edge of highway by 2 dBA at Site 1 and Site 2, and by 5 dBA at Site 3. The depressed geometry of the highway at these locations most likely affected these predictions. Sensitive receptor noise measurements without a noise barrier were somewhat higher than predicted; however, measurements with the noise barrier in place were lower than expected. The net result was that at each Site, the barrier insertion loss was greater than predicted, and therefore, the noise level at each sensitive receptor was lower than predicted.

D. Economics

Fifty-six apartment units were protected from excessive noise impact by the barrier installation near the Clayton Arms Apartment Complex at Site 1. At a total cost of $258,021, the cost to reduce the noise impact was $4,608 per unit.

At Site 2, Wedgewood Park Subdivision, seven residential properties were protected by the barrier installation at a total cost of $132,925 or $18,989 per property.

At Site 3, 22 apartment units were protected at the Community Manor Apartment Complex at a total cost of $59,995 or $2,727 per unit.

IV. SUMMARY

A. Findings

The FANWALL modular concrete noise barrier/berm installations effectively reduced noise levels at sensitive receptors. Noise level reductions as determined by insertion loss measurements ranged between 13 and 16 dBA. In each case the noise at the sensitive receptor was reduced to a level below the target level found in the EIS.

Although the trapezoidal configuration of the FANWALL barriers was intended by the designers to be free-standing, a foundation retrofit was required on the three installations studied. The cost of the additional foundation work raised construction costs on the installations studied by between 22% and 63%. The final cost of the barrier installations ranged between $71.85 and $117.28 per linear ft ($7.46 to $10.56 per sq ft.) The variation in cost was significantly affected by the barrier height and the degree of foundation retrofit required at each site.

To date, the barrier installations have proven to be maintenance free. Aesthetically, the barriers blend well with the surrounding landscape.

The HUSH noise level prediction program proved to be a good noise prediction tool. The edge-of-highway noise measured was from 2 to 5 dBA more than the predicted values. Sensitive receptor noise levels without a noise barrier were between 2 and 6 dBA higher than the predicted levels. Barrier insertion losses measured between 5 and 11 dBA lower than predicted -- erring on the conservative side. Overall, the differences noted tended to cancel each other.

B. Conclusions

The FANWALL modular precast concrete noise wall system in combination with an earth berm can provide effective traffic noise reduction. It is an economically attractive method of mitigating traffic noise level impacts, aesthetically acceptable and is essentially maintenance free. Even when configured in the free-standing trapezoidal design, a foundation treatment may be required when used in plastic soils, especially at the barrier ends.

C. Recommendations

The FANWALL precast concrete modular panel/berm noise barrier system with adequate foundation design should be allowed as a standard construction alternative on New York State contracts, where appropriate.

V. ACKNOWLEDGEMENTS

Acknowledgement is greatfully made to the many people both within and outside the New York State Department of Transportation who were involved in the design, construction and evaluation of the subject noise barriers. Special mention is made of the contributors to this report including (in alphabetical order):

Cathy Cowan, Materials Bureau - Noise Measurement and Analysis
Denise DeVito, Materials Bureau - Typing
Sonny DiCenzo, Region 4 Materials Engineer - Records/Information
Allen Frank, Materials Bureau - Graphics
Eileen Frederick, Materials Bureau - Typing
Karl Horn, Region 4 EIC D95646 - Records/Information
Joseph Micare, Materials Bureau - Graphics
Thomas Nelson, Materials Bureau - Noise Measurement
Paul Towlson, Region 4 Noise Measurement Liaison - Data

VI. REFERENCES

1. Project Report V: Final Environmental Impact Statement, The Genesee Expressway (I-390), Report Number FHWA-NY-EIS-73-12-F, 1977.

2. Highway Noise, A Design Guide for Highway Engineers, National Highway Research Program, Publication 117, 1971.

3. Highway Noise, A Field Evaluation of Traffic Noise Reduction Measures, National Highway Research Program, Publication 144, 1973.

4. Fundamentals and Abatement of Highway Traffic Noise, Federal Highway Administration, U.S. Department of Transportation, Report FHWA-HHI-HEV-73-7976-1, 1973.

5. Field Measurement of Existing Noise Levels, New York State Department of Transportation, Materials Bureau, Noise Measurement Unit, 1976 Revision.

6. Noise Measurement Systems Operating Instructions, New York State Department of Transportation, Materials Bureau, Noise Measurement Unit, 1976.

VII. APPENDICES

A. Noise Barrier Profiles

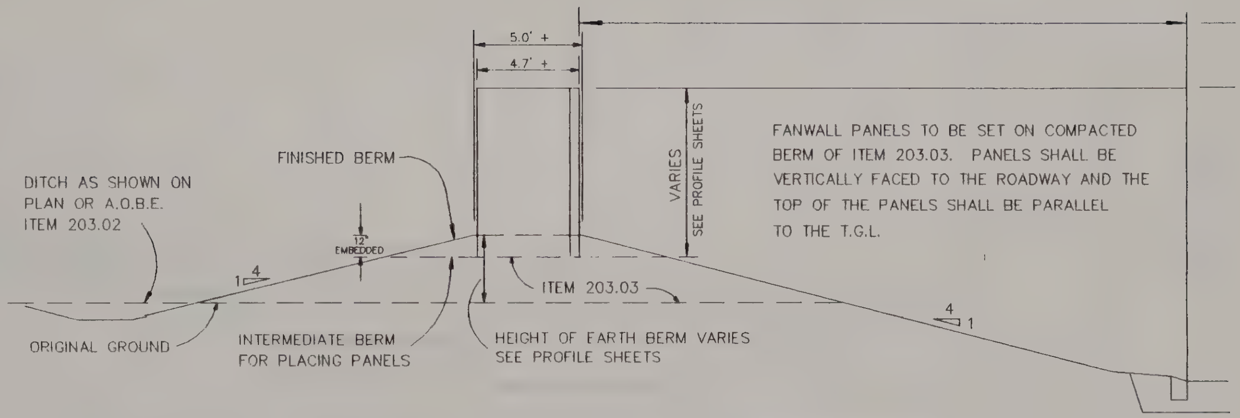
B. FANWALL Panel Wall System

C. Item 04607.7011 Modular Concrete Panels

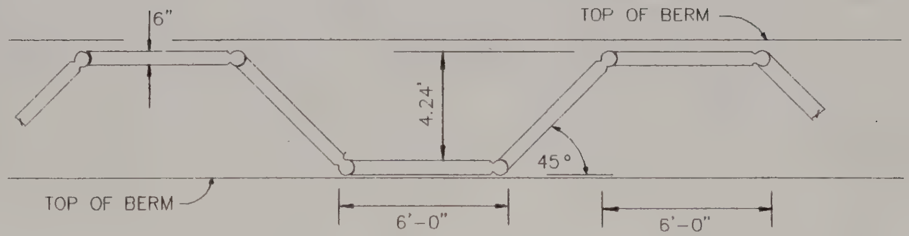
D. FANWALL Production Guideline

APPENDIX A

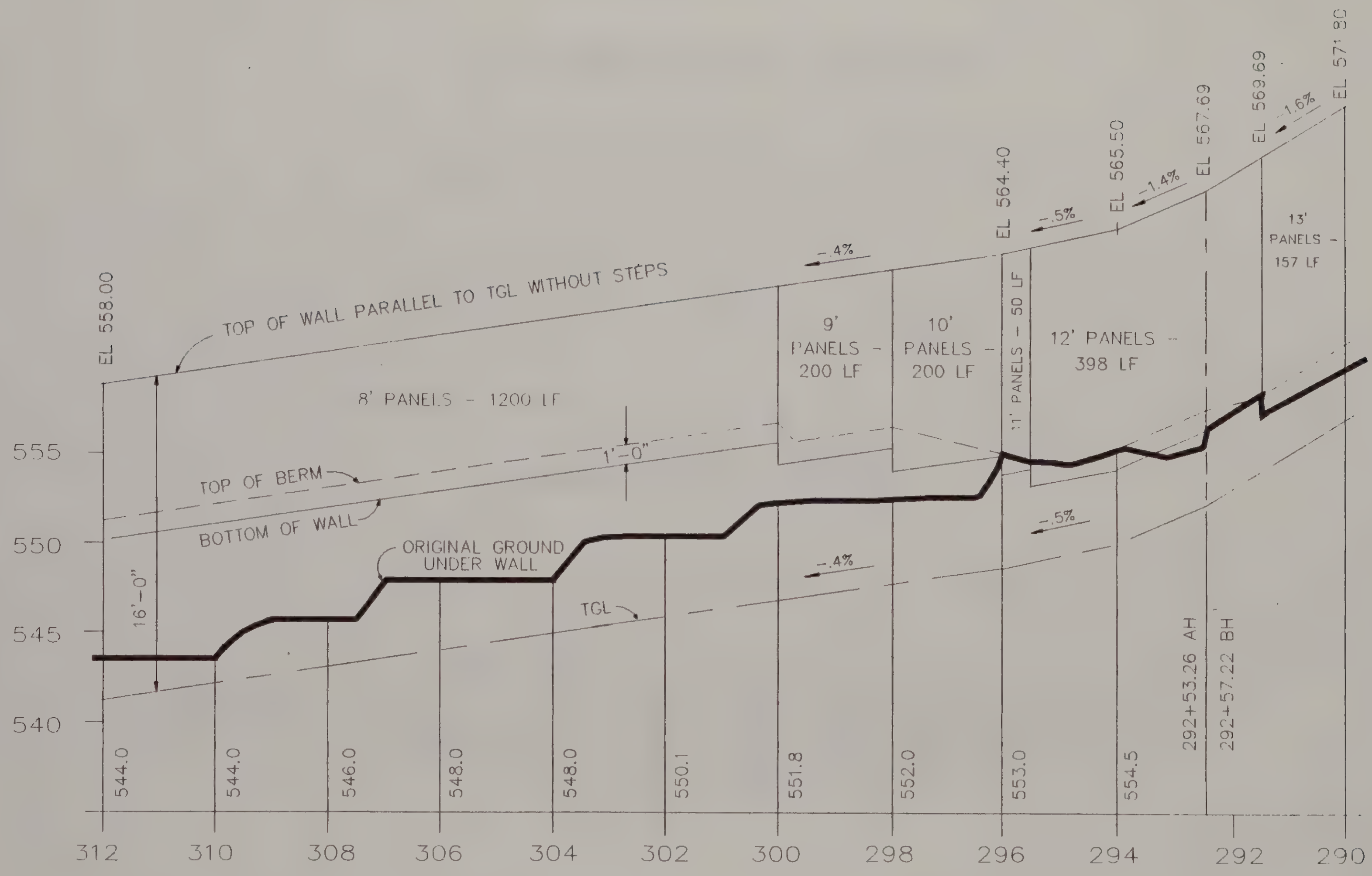
Noise Barrier Profiles



FANWALL TYPICAL SECTION

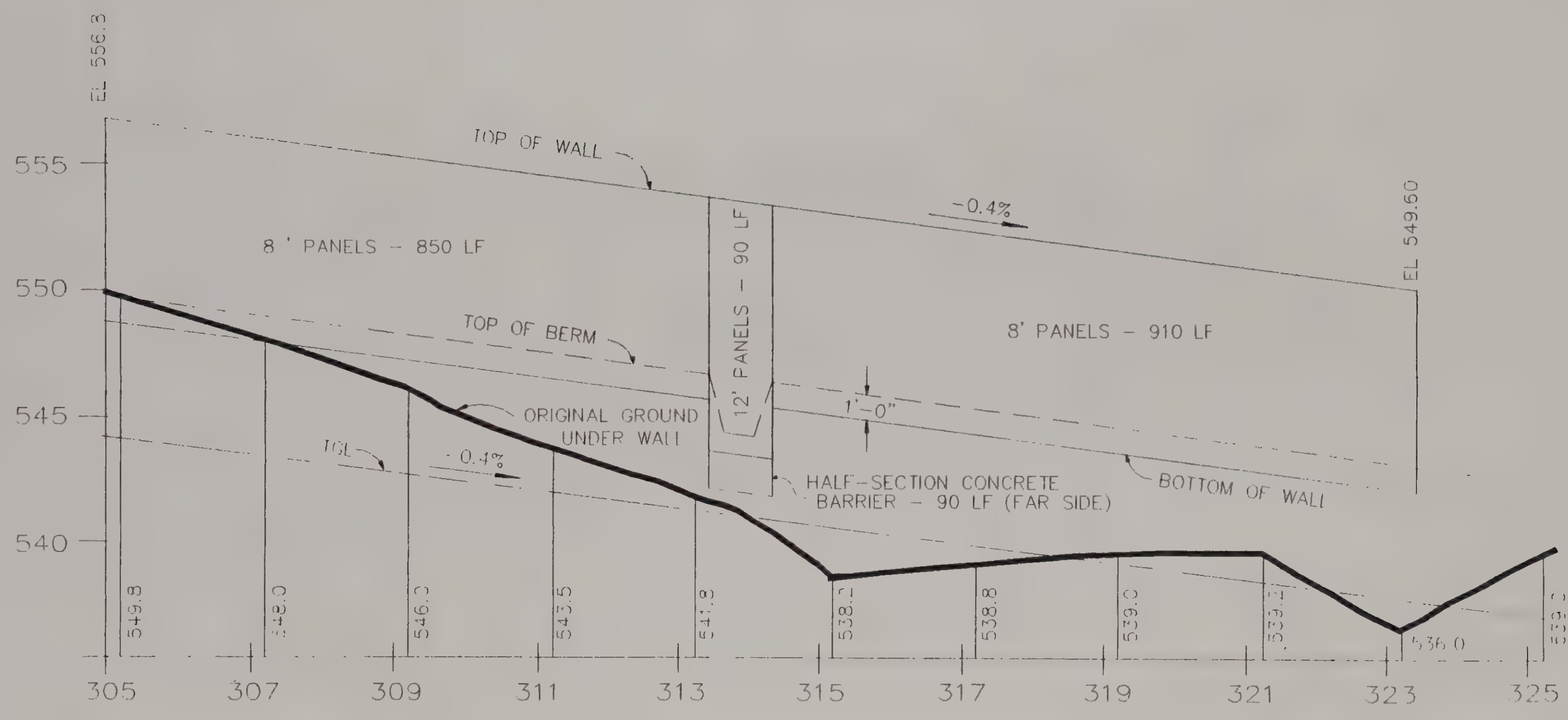


PLAN VIEW FANWALL MODULES



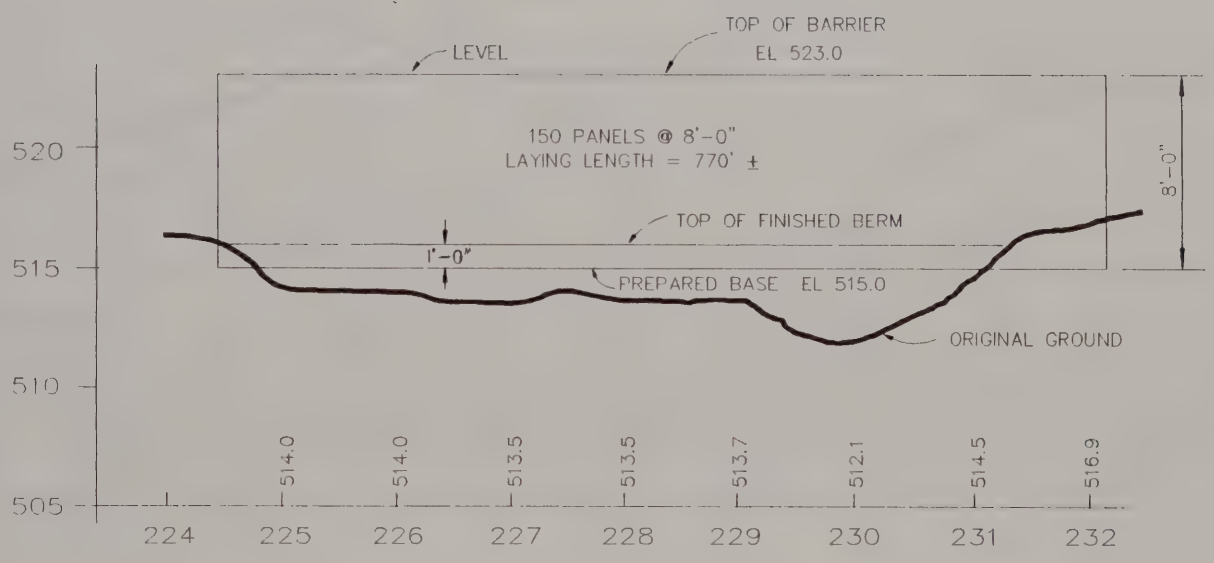
FANWALL PROFILE -- SITE 1

STA SB 290+00 TO SB 312+00



FANWALL PROFILE -- SITE 2

STA NB 305+00 TO NB 323+50

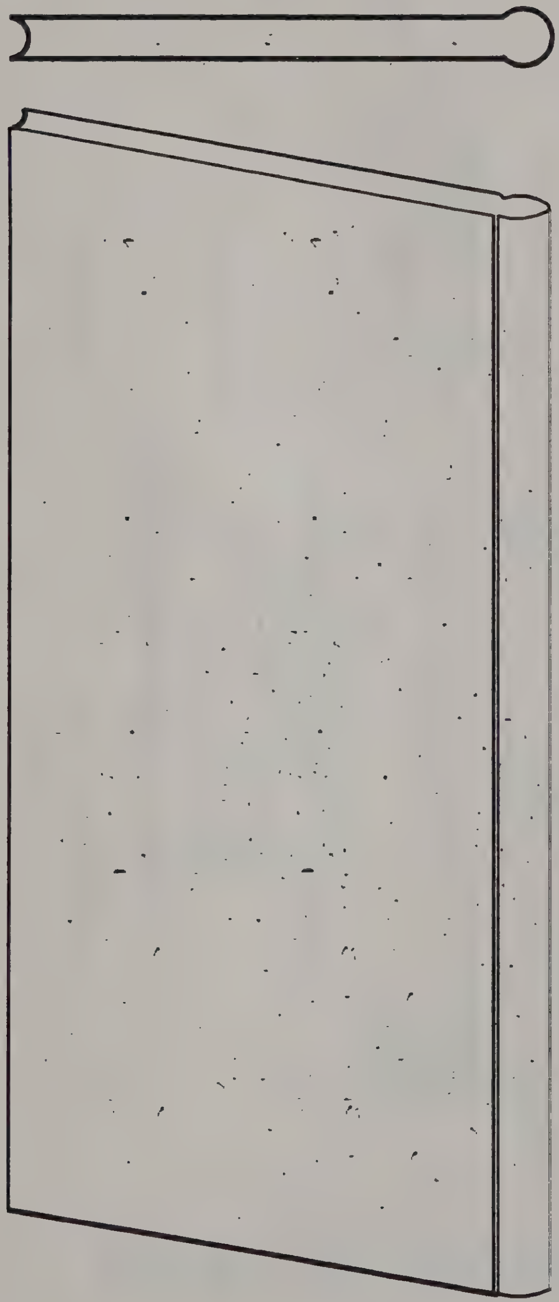


FANWALL PROFILE -- SITE 3

STA SB 224+45 TO SB 232+15

APPENDIX B

FANWALL Panel Wall System



FANWALL MODULE

PANEL DIMENSIONS

HEIGHT: TO 20'

WIDTH: 4' TO 8'

THICKNESS: 4" TO 5"

TYPICAL: 10" x 5' x 5"
(SHOWN)

MATERIALS

CONCRETE: 3000 PSI (MIN)

STEEL: 4 x 4 6/6 WWF (MIN)

WEIGHT

12.5 LBS/SF/INCH THICK

SOUND TRANSMISSION LOSS

36 dBA

OPTIONS

TRANSPARENCIES
SOUND ABSORBING FACES

ADD-ONS POSSIBLE LATER

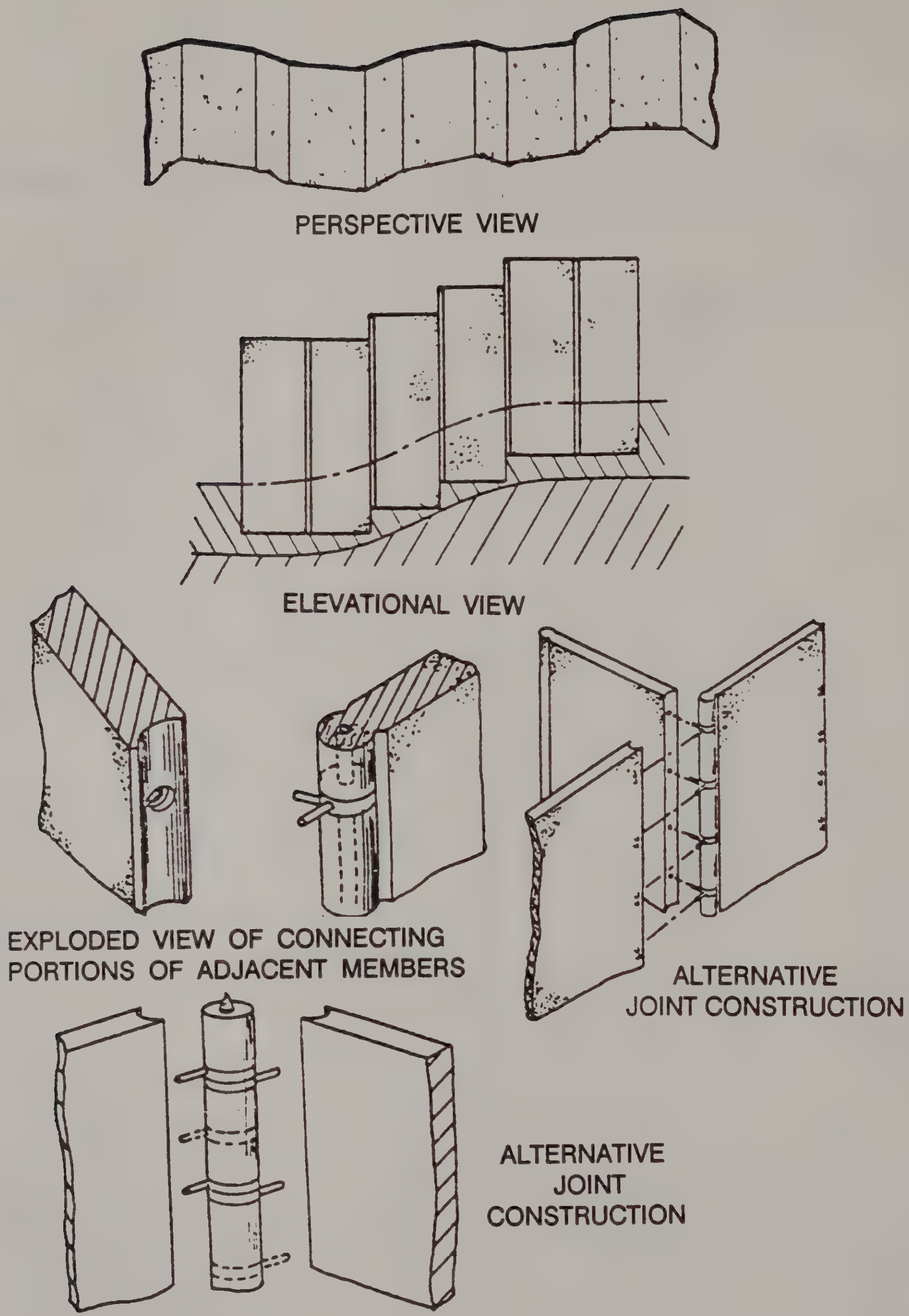
ENDS: CONTINUATIONS

T SPURS

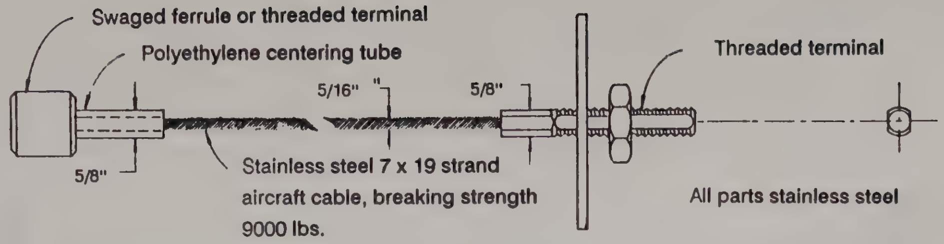
HEIGHT INCREMENTS

PANEL EXCHANGES

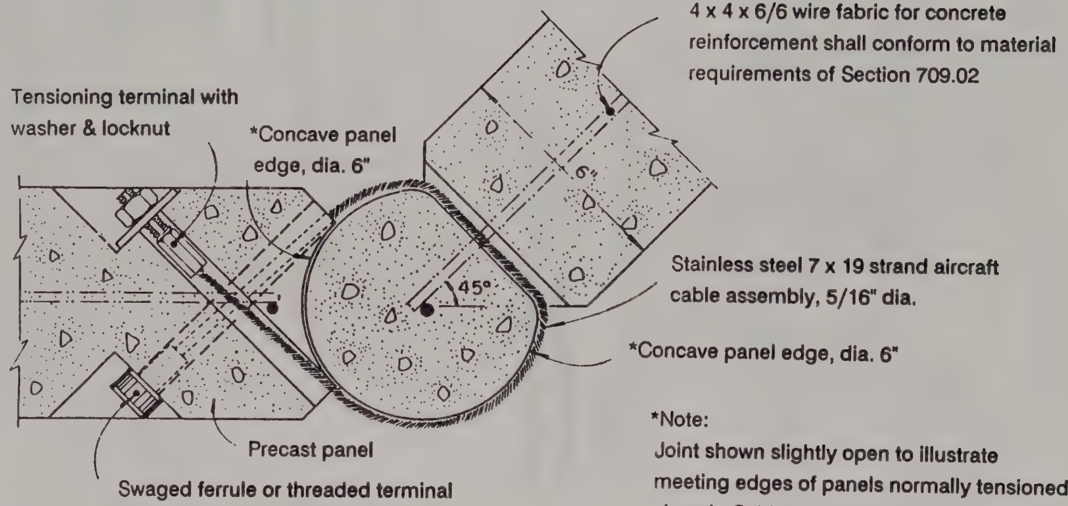
SOUND ABSORBING FACES



FANWALL INTERLOCKING PANEL WALL SYSTEM



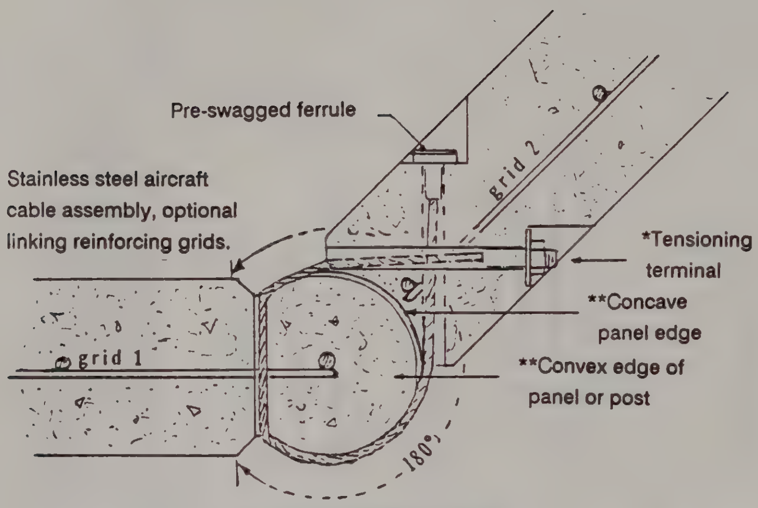
CABLE CONNECTOR ASSEMBLY
(NOT TO SCALE)



U.S. Patent
No. 3732653

JOINT SYSTEM SCHEMATIC
(SECTION IN PLAN)

*Note:
Joint shown slightly open to illustrate meeting edges of panels normally tensioned closed. Cable to be tensioned as necessary to insure the stability and position of adjacent panels.



*Tension by nut, bolt or pull-swage hardware as furnished.

**Joint shown slightly open to illustrate meeting edges normally tensioned closed.

NOTES

A. GRID: 4 x 4 6/6 WWF (min.)

B. CABLE: Stainless steel 7 x 19 strand aircraft type

Rated tensile:

1/8" 1760 lbs.
5/32" 2400 lbs.
3/16" 3700 lbs.

C. CLAMPS: Compression fittings hold to full-rated tensile strength of cable.

D. FASTENING: Field tensioned and crimped prior to crane release.

E. FASTENER QUANTITY & SIZE: Relative to panel size (= weight). Note that "loop" effectively doubles cable and there are 4 loops min. (2 per joint) for total support as required.

PLAN

FANWALL ASSEMBLY

50313-1

APPENDIX C

Item 04607.7011 Modular Concrete Panels

ITEM 04607.7011 MODULAR CONCRETE PANELS

1. Description

Under this Item, the Contractor shall furnish and place modular concrete panels upon properly prepared sub-grades as indicated on the plans or as ordered by the Engineer.

2. Materials

Modular panels shall be rectangular in shape with nominal size 72 inches wide and 6 inches thick. The height of the panels shall vary in increments of one foot from 8 feet to 13 feet as shown on the plans. Permissible tolerances are as follows:

Height: ±1/2 inch
Width: ±1/2 inch
Thickness: +1/4 inch

The concrete shall meet the requirements of Class A Concrete in Section 501, Portland Cement Concrete - General, except that the requirements for inspection facilities, automated batching controls and recordation do not apply. The batching, mixing and curing methods, and the inspection facilities shall meet the approval of the Department or its representative. The Contractor may submit, for approval by Deputy Chief Engineer, Technical Services, a mix at least equivalent to the specified Class A Concrete.

Steel reinforcement for cement concrete shall conform to the requirements specified under 709-02, Wire Fabric for Concrete Reinforcement.

Fasteners shall be stainless steel 7 x 19 strand aircraft cable with a minimum rated tensile strength of 9,000 pounds and a minimum diameter of 5/16 inches. Tensioning clamps shall be compression fittings with a rated tensile strength equal to or exceeding the strength of the cable.

Modular concrete panels and fasteners shall be equal as approved to the FANWALL MODULE, U.S. Patent No. 3732653, as assigned to FANWALL, INC., P.O. Box 868, Framingham, Massachusetts 07101.

3. Construction Details

The general construction details for manufacturing, placing, and curing concrete shall meet the Standard Specification requirements in 501-3 for Portland Cement concrete.

Wire fabric for concrete reinforcement, 709-02, shall be embedded at mid-depth in the panel.

The edges and back side of each panel shall be finished to provide a smooth and uniform surface. The remaining surface that will face the roadway shall be textured with a broom in a direction parallel to the vertical axis of the installed panel. Striations shall be generally not less than 1/16 inch nor greater than 1/8 inch deep in the plastic concrete. The spacing of the striations shall be approximately the same as the depth of the striations. The capability of the broom to obtain acceptable striations shall be demonstrated to the Engineer prior to approval for use.

Final curing shall conform in methods with the recommendations of the manufacturer. No curing material shall be used that will discolor the surface of the modular panels.

The Contractor shall construct a sample 8 foot by 6 foot panel 6 inches in thickness to demonstrate the methods and materials to be used. This sample panel shall be available on the construction site for inspection and comparison. The panel shall be cast prior to final approval of the modular concrete panels and shall be considered as part of the test requirements for this Item. Upon acceptance by the Engineer, the sample panel may be installed and paid for under this Item.

Modular panels shall be set vertically faced to the roadway with the top of the panels paralleling the roadway grade to produce a smooth appearance. Panels shall be installed in a trapezoidal configuration on the earth berm with an intersecting angle between panels of 45°. After angle is set, fasteners shall be inserted and field tensioned as necessary to insure the stability and position of the panel. Tensioning clamps shall be crimped prior to crane release.

The Contractor shall protect the modular concrete panels and keep them in first class condition until the completion and acceptance of the contract. Any panels damaged at any time prior to final contract acceptance shall be replaced or repaired at the Contractor's expense.

4. Method of Measurement

Modular concrete panels shall be measured by the actual number of square feet properly installed.

5. Basis of Payment

The unit price bid per square foot of this Item shall include the cost of furnishing all equipment, materials, and labor necessary to complete the work.

APPENDIX D

FANWALL Production Guideline

FANWALL PRODUCTION GUIDELINE

A. DESCRIPTION OF PLANT FACILITIES

1. Casting Bed
   10' x 100' steel table indoors, with all steel edge molds.

2. Batching Plant
   Central mix plant with a one yard turbine mixer.

3. Consolidation Equipment
   The plastic concrete will be consolidated in place by external form mounted vibrators and/or internal vibration.

4. Transporting Equipment
   Concrete is carried from the central mix to the forms by bucket. Finished product will be lifted from casting tables by vacuum lifter and moved on flat bed trucks to storage.

5. Quality Control Equipment
   a. Recording thermometer.
   b. Schmidt test hammer.
   c. Cylinders are broken by a commercial lab.

6. Storage
   Members will be stored in outside storage yard on non-staining dunnage or directly on other concrete members.

B. CONCRETE DATA

1. Concrete Strength - 3,000 psi @ 28 day minimum

2. Design Mix

Design Mix	Weight	Volume	Ratio
Cement	705#	3.59	7½
Sand	1135#	6.81	40% S/A
Aggregate (NYS#1)	1715#	10.18	
Water	290#	4.64	0.41 W/C
Air	6.6%	1.78	
Slump	2 to 3"	27.00	
Darex AEA	8 oz.		
WRDA with Hycol	21 oz.	or Daratard 17	

3. Suppliers
   a. Cement Type 2: Rochester Portland
   b. Aggregate NYS #1 and Concrete Sand: Valley Sand & Gravel
   c. Admixtures: W.R. Grace, Construction Products Division

4. Test Cylinders
Concrete strength will be determined from test cylinders made in accordance with ASTM-C31, except that all cylinders shall be vibrated. All cylinders shall be tested in accordance with ASTM-C39 on an approved testing machine (Fact Geotechnical Services). A minimum of 3 cylinders will be taken daily. Cylinders will be cured with the members until removal from forms, then 2 stored in a curing cabinet until 28 day test, and 1 yard stored with the members until 28 day test.

C. STEEL DATA

1. Wire fabric for concrete reinforcement shall meet the requirements of 709-02.

2. Supplier: Exposaic Wire

D. MISCELLANEOUS DATA

1. Adequacy of lifting device is fabricator's responsibility.

2. Identifying piece marks for each unit will be placed on its bottom end or face.

E. CURING PROCEDURE

1. Members will be covered with polyethylene tarps after casting and finish brooming, and kept covered until removal from forms to insure moisture retention for complete hydration of cement and to prevent formation of surface cracks due to rapid loss of water. The initial curing phase for each unit shall be the period beginning at the time each unit is completely covered and continuing until the final curing phase commences. The initial set time of each member is 2 to 6 hours.

2. The final curing phase for each unit shall be that period required to raise the initial curing phase temperature to 130°F ± 20° until removal from forms.

3. No curing material shall be used that will discolor the surface of the modular panels.

F. FINISHING

1. All exposed corners will be form chamfered.

2. The edges and back side of each panel will be as cast against smooth steel form surfaces. The remaining surface shall be textured with a broom in a direction parallel with the vertical axis of the installed panel. Striation should be generally not less than 1/16" nor greater than 1/8" deep in the plastic panel.

3. Lifting insert holes will be filled with a neat cement grout after panel erection.

G. TOLERANCES

1. Precasting
   Modular panels shall be rectangular in shape with nominal sizes as shown on plans and approved shop drawings. Permissible tolerances are as follows:
   a. Height: ±½"
   b. Width: ±½"
   c. Thickness: ±¼"
   d. Position of fastener locator: ±¼"
   e. Position of mesh: ±1"

2. Modular concrete panels shall be equal as approved to the FANWALL MODULE, U.S. Patent No. 3732653, as assigned to FANWALL INC., P.O. Box 868, Framingham, Massachusetts 07101.

3. Shipping
   a. Units shall not be shipped until the minimum 28 day strength has been attained, but in no case, before 48 hours storage time has elapsed following casting.
   b. Members will be loaded onto flat bed trailers using either slings or vacuum lifters.
   c. Units will be removed from trucks and set into final position using the cast in top lifting inserts.
   d. Erection weight for a typical member 6' x 8' x 6" thick is 3,600 pounds.

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